# WEST ATCHAFALAYA BORROW PIT CANAL

# TMDL FOR SULFATE AND SALINITY/TOTAL DISSOLVED SOLIDS

# SUBSEGMENT 060211

US EPA Region 6

Final

May 3, 2001

## TABLE OF CONTENTS



## LIST OF TABLES

## EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A total maximum daily load (TMDL) is the amount of a pollutant that a waterbody can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads can be distributed or allocated to point sources and nonpoint sources discharging to the waterbody. A TMDL has been developed for sulfate and salinity/TDS for the West Atchafalaya Borrow Pit Canal.

West Atchafalaya Borrow Pit Canal (subsegment 060211) flows from its headwaters near Bayou Courtableau in South Central Louisiana to the city of Henderson, and includes Bayou Portage. Subsegment 060211 was listed on the 1998 Court Ordered §303(d) list as not fully supporting the water quality standard for propagation of fish and wildlife and was ranked as high priority for TMDL development. Louisiana's water quality standards for chloride, sulfate, and TDS are applied as follows:

"Numerical criteria for these parameters generally represent the arithmetic mean of existing data from the nearest sampling location plus three standard deviations. For estuarine and coastal marine waters subsegments in Table 3 that have no listed criteria (i.e., designated N/A), criteria will be established on a case-by-case basis using field determination of ambient conditions and the designated uses. For water bodies not specifically listed in the Numerical Criteria and Designated Table, increases over background levels of chloride, sulfate, and TDS may be permitted. Such increases will be permitted at the discretion of the office on a case-by-case basis and shall not cause in-stream concentrations to exceed 250, 250, and 500 mg/l for chloride, sulfate, and TDS, respectively, except where a use attainability analysis indicates that higher levels will not affect the designated uses. In permitting such increases, the office shall consider their potential effects on resident biota and downstream water bodies in addition to the background conditions. Under no circumstances shall an allowed increase over background conditions cause any numerical criteria to be exceeded in any listed water body or any other general or numerical criteria to be exceeded in either listed or unlisted water bodies."

Six months (June, 1998 – December, 1998) of monthly LDEQ monitoring data on the West Atchafalaya Borrow Pit Canal (WQ site 671) were assessed to determine if the propagation of fish and wildlife use was being maintained. Analysis of the data shows that the propagation of fish and wildlife use is not protected. Salinity/TDS data were not available and were therefore estimated. TDS can be estimated by multiplying conductivity values by a multiplier. For the analyses of natural waters, the multiplier ranges between 0.55 and 0.96, the higher values generally being associated with waters high in sulfates (Hem, 1985). For this data set, 1.02 was calculated as a multiplier using data from a similar station (WQ site 0101). Seventy-five percent of the measurements exceeded both the sulfate criterion of 30mg/l and the TDS criterion of 220 mg/l (see Appendix A). Therefore, a TMDL was developed to protect the propagation of fish and wildlife use.

The sulfate TMDL was developed based on simple dilution calculations using average flow and the state sulfate criterion of 30 mg/L for this subsegment. Likewise, the salinity/TDS TMDL was developed based on simple dilution calculations using average flow and the state TDS criterion of 220 mg/L for this subsegment. The TMDL calculation for both criteria includes a wasteload allocation, a load allocation, and a margin of safety. A 6% reduction in sulfate

loading and 35% reduction in salinity/TDS loading will be needed to meet the standard for the propagation of fish and wildlife.

## 1. Introduction

West Atchafalaya Borrow Pit, subsegment 060211, was listed on the October 28, 1999 Court Ordered §303(d) lists as not fully supporting the water quality standard for the propagation of fish and wildlife. Subsegment 060211 was ranked as a high priority for TMDL development. A TMDL for sulfate and salinity/TDS was developed in accordance with the requirements of Section 303(d) of the federal Clean Water Act. The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standard for that pollutant; the TMDL also establishes the load reduction that is necessary to meet the standard in a waterbody. The TMDL consists of the wasteload allocation (WLA), the load allocation (LA), and a margin of safety (MOS). The wasteload allocation is the load allocated to point sources for the pollutant of concern and the load allocation is the load allocated to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for the uncertainty associated with the model assumptions and data inadequacies.

## 2. Study Area Description

### 2.1 West Atchafalaya Borrow Pit, Subsegment 060211

West Atchafalaya Borrow Pit flows through the Vermilion-Teche River Basin in South Central Louisiana. The Vermilion-Teche River Basin lies in the Western Gulf Coastal Plain ecoregion. The watershed is characterized as plains/prairie, and the land is generally flat with a very gradual slope toward the Gulf of Mexico. Subsegment 060211 runs from Bayou Courtableau just south of Highway 190 to Henderson, LA. This subsegment also includes Bayou Portage. Water is pumped through Bayou Darbonne from the Atchafalaya River Basin to Bayou Courtableau. Excess water from Bayou Courtableau then flows over two spillways and into the West Atchafalaya Borrow Pit. The major land uses are listed in Table 1 (LDEQ 1993).

Table 1. Land Use (acres) in subsegment 0602 of the Vermilion-Teche River Basin

| URBAN | EXTRACTIVE | AGRICULTURAL | FOREST | WATER | WETLAND |
|---|---|---|---|---|---|
| 46942 (4.5%) | 3450 (0.3%) | 676490 (64.1%) | 245115 (23.2%) | 5180 (0.5%) | 73230 (6.9%) |

### 2.2 Water Quality Standards

The designated uses for the West Atchafalaya Borrow Pit include primary and secondary contact recreation and the propagation of fish and wildlife. Sulfate and salinity/TDS are water quality indicators used for assessment of use support. Louisiana's water quality criteria for sulfate and TDS are 30 mg/L and 220 mg/L, respectively (Subsegment 060211).

It is worth noting that the primary source of water flowing into the West Atchafalaya Borrow Pit Canal is from water being pumped through Bayou Darbonne from the Atchafalaya River Basin to Bayou Courtableau. Bayou Courtableau then flows primarily west into Bayou Teche. Backwaters from Bayou Courtableau, when high enough, flow over two spillways and into the West Atchafalaya Borrow Pit. Sulfate and TDS water quality criteria, 70 mg/L and 440 mg/L respectively, for the Atchafalaya River Basin are much greater than those for the Vermillion-

Teche River Basin, 30 mg/L and 220 mg/L respectively. Therefore, the inter-basin pumping of waters from the Atchafalaya River Basin to the Vermilion-Teche River Basin is influential on the sulfate and TDS concentrations in the West Atchafalaya Borrow Pit Canal and is a probable reason as to why the sulfate and TDS water quality standards are not being met.

### 2.3 Identification of Sources

The sources identified on the 1999 court ordered 303(d) list as affecting the water quality of West Atchafalaya Borrow Pit are designated as minor municipal point sources, package plants, non-irrigated crop production and septic tanks.

#### 2.3.1 Point Sources

There are 5 permitted facilities with known flow information and 1 permitted facility with unknown flow information discharging wastewater into subsegment 060211. Flow was estimated at 1,000 gallons per day for the facility with unknown flow information. The combined flow of all these discharges is 69,000 gallons per day (see Table 2).

Table 2. Dischargers in Subsegment 060211

| Facility | Permit # | Flow (MGD) |
|---|---|---|
| Florida Gas Transmission Co | LAG530969 | 0.005 |
| Little Capital Restaurant of Louisiana | LAG540922 | 0.025 |
| Louisiana Royal Seafood Inc. | LA0099571 | 0.030 |
| Access Oil Tools, Inc. | LAG530028 | 0.005 |
| Florida Gas Transmission Co | LA0108910 | 0.001* |
| NAD Seafood Substation No. 1 | LA0081051 | 0.003 |
| Total | | 0.069 |

*flow information unknown; flow estimated as 1000 gallons/day (0.001 MGD)

#### 2.3.2 Nonpoint Sources

Land uses in the West Atchafalaya Borrow Pit drainage area contribute sulfate and salinity/TDS loads through runoff. The significant NPS source is non-irrigated crop production.

## 3. TMDL Load Calculations

### 3.1 Sulfate and Salinity/TDS Current Load Evaluation

Sulfate and salinity/TDS loads have been calculated using the instream sulfate and estimated TDS concentrations and the flow of the stream. The following equation can be used to calculate sulfate and salinity/TDS loads.

Equation 1. C x Q in cfs x 5.39 lb/day or C x Q in MGD x 8.34 lb/day

Where: C = concentration in mg/L
Q = stream flow in cfs or MGD

A traditional expression of the loading may be developed by setting one critical or representative flow and concentration, and calculating the sulfate or salinity/TDS load using Equation 1. The difficulty with this approach is in the determination of the appropriate flow or concentration value to use.

For the purpose of calculating current loading on this water body, the average sulfate and salinity/TDS concentrations were calculated using monthly LDEQ monitoring data on the West Atchafalaya Borrow Pit Canal (WQ site 671). WQ site 671 was used because it has the most recent sulfate and conductivity data. Salinity/TDS data were not available and were therefore estimated by multiplying the conductivity values by a multiplier.

A multiplying factor was developed using the available field conductivity and TDS data from LDEQ water quality station 0101 at Bayou Courtableau. The data available at this station is from March, 1988 through December, 1990. Since there was only one year of data from Station 0671, the most recent year of sulfate and conductivity data from station 0101 (1990) was used in an ANOVA to determine if the values were similar between stations (Appendix C). Since there was no statistically significant differences in sulfate concentrations ($p < 0.30$, $n=12$) or conductivity values ($p < 0.91$, $n=12$) between the two stations, the data from station 0101 were used to calculate a multiplying factor. Dividing TDS values (mg/l) by field conductivity values ($\mu$mhos) for each sampling date and then taking the average resulted in a multiplying factor of 1.02 mg/l/$\mu$mho. TDS was then estimated by multiplying the field conductivity data from WQ station 0671 on the West Atchafalaya Borrow Pit Canal (June, 1998 – December, 1998) by the multiplier (1.02 mg/l/$\mu$mho).

In the West Atchafalaya Borrow Pit Canal, the monthly sulfate concentrations ranged from 5.8 mg/L to 53.7 mg/L over a seven-month period (June, 1998 – December, 1998). The average sulfate concentration was 32.0 mg/L. Likewise, the monthly estimated TDS concentrations ranged from 130 mg/L to 470 mg/L over the same period. The average TDS concentration was 340 mg/L (see Appendix A).

For the purpose of calculating current loading on this waterbody, the average flow was calculated using the methodology described in Appendix B. Based on this methodology, the average flow for the West Atchafalaya Borrow Pit Canal (subsegment 060211) was 150 $ft^3$/sec

(Appendix B). Using these values and Equation 1 it is estimated that the current sulfate loading is 25,872 lb/day and the current salinity/TDS loading is 274,890 lb/day.

### 3.2 TMDL

Point sources usually have a defined critical receiving stream low flow such as the 7Q10 (or Harmonic mean flow) at which the criterion must be met. For nonpoint sources it is recognized that there may be no single critical flow condition. The sulfate load reduction needed to meet the water quality standard for propagation of fish and wildlife in West Atchafalaya Borrow Pit Canal at 150 cfs is 1617 lb/day (6 % reduction). This was obtained by calculating the allowable TMDL at 150 cfs for the 30mg/L criterion (24,255 lb/day) and subtracting this load from the observed load (25,872 lb/day). Likewise, the TDS load reduction needed to meet the water quality standard for propagation of fish and wildlife in West Atchafalaya Borrow Pit Canal at 150 cfs is 97,020 lb/day (35 % reduction). This was obtained by calculating the allowable TMDL at 150 cfs for the 220 mg/L criterion (177,870 lb/day) and subtracting this load from the observed load (274,890 lb/day).

TMDL= Cstd x Q cfs x 5.39 lb/day, where Cstd= 30 mg/l for sulfate and 220 mg/l for TDS
Q= 150 cfs

Sulfate TMDL= 30mg/l x 150cfs x.5.39lb/day = 24,255 lb/day
TDS TMDL= 220mg/l x 150cfs x 5.39lb/day = 177,870 lb/day

Current Load - TMDL = Load Reduction

25,872 lb/day – 24,255 lb/day = 1617 lb/day for Sulfate
274,890 lb/day – 177,870 lb/day = 97,020 lb/day for TDS

### 3.3 Wasteload Allocation (WLA)

The Louisiana Water Quality Regulations require permitted point source discharges of treated sanitary wastewater to maintain an in-stream sulfate concentration of 30 mg/l and an in-stream TDS concentration of 220 mg/L (Subsegment 060211). Equation 1 can be used to calculate individual point source wasteload allocations utilizing a sulfate concentration of 30 mg/L and a TDS concentration of 220 mg/L and the total volume of wastewater per discharger (See Table 3).

30 mg/L * Q in MGD * 8.34 = Sulfate WLA
220 mg/L * Q in MGD * 8.34 = Salinity/TDS WLA

Where Q = Total volume of wastewater discharges into the West Atchafalaya Barrow Pit Canal (0.069 MGD)

Sulfate WLA for all dischargers = 17.27 lb/day

Salinity/TDS WLA for all dischargers = 126.58 lb/day

Table 3. Salinity/TDS and Sulfate Wasteload Allocations

| Facility | Permit # | Flow (MGD) | Salinity/TDS Load (lb/day) | Sulfate Load (lb/day) |
|---|---|---|---|---|
| Florida Gas Transmission Co | LAG530969 | 0.005 | 9.17 | 1.25 |
| Little Capital Restaurant of Louisiana | LAG540922 | 0.025 | 45.87 | 6.26 |
| Louisiana Royal Seafood Inc. | LA0099571 | 0.030 | 55.04 | 7.51 |
| Access Oil Tools, Inc. | LAG530028 | 0.005 | 9.17 | 1.25 |
| Florida Gas Transmission Co | LA0108910 | 0.001 | 1.83 | 0.25 |
| NAD Seafood Substation No. 1 | LA0081051 | 0.003 | 5.50 | 0.75 |
| Totals | | 0.069 | 126.58 | 17.27 |

### 3.4 Load Allocation (LA)

The load allocation for sulfate or salinity/TDS at a given flow can be calculated using Equation 1 and the following relationship:

(TMDL@ given flow and criterion) - (WLA) = LA

Sulfate LA for instream flow of 150 cfs = 24,237.73 lb/day
24,255 lb/day (TMDL @150 cfs) – 17.27 lb/day (WLA) = 24,237.73 lb/day

Salinity/TDS LA for instream flow of 150 cfs = 177,743.42 lb/day
177,870 lb/day (TMDL@ 150 cfs) – 126.58 lb/day (WLA) = 177,743.42 lb/day

### 3.5 Seasonal Variation

Louisiana's water quality standard for sulfate and TDS is 30 mg/L and 220 mg/L, respectively, for January through December. Therefore, no seasonal TMDL for sulfate and salinity/TDS was developed.

### 3.6 Margin of Safety (MOS)

The Clean Water Act requires that TMDLs take into consideration a margin of safety. EPA guidance allows for the use of implicit or explicit expressions of the margin of safety or both. When conservative assumptions are used in the development of the TMDL or conservative factors are used in the calculations, the margin of safety is implicit. When a percentage of the load is factored into the TMDL calculation as a margin of safety, the margin of safety is explicit. In this TMDL for sulfate and TDS, conservative assumptions have been used and therefore, the margin of safety is implicit. These conservative assumptions are:

- Using average flows to calculate current loading to obtain load reduction.

- Treating sulfate and TDS as conservative pollutants, that is, a pollutant that does not degrade in the environment.
- Using the sulfate water quality standard of 30 mg/l and the TDS water quality standard of 220 mg/l rather than using site-specific criteria and seasonal variability factors.
- Using the design flow (where available) of the point source dischargers rather than actual average flow rates, which are typically much lower.

**4. Other Relevant Information**

Although not required by this TMDL, LDEQ utilizes funds under Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act to operate an established program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following establishment of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list. The sampling schedule for the first five-year cycle is shown below. The Vermilion-Teche River Basin will be sampled again in 2003.

1998 – Mermentau and Vermilion-Teche River Basins
1999 - Calcasieu and Ouachita River Basins
2000 – Barataria and Terrebonne Basins
2001 – Lake Pontchartrain Basin and Pearl River Basin
2002 – Red and Sabine River Basins

(Atchafalaya and Mississippi Rivers will be sampled continuously.)

In addition to ambient water quality sampling in the priority basins, the LDEQ has increased compliance monitoring in those basins, following the same schedule. Approximately 1,000 to

1,100 permitted facilities in the priority basins were targeted for inspections. The goal set by LDEQ was to inspect all of those facilities on the list and to sample 1/3 of the minors and 1/3 of the majors. During 1998, 476 compliance evaluation inspections and 165 compliance sampling inspections were conducted throughout the Mermentau and Vermilion-Teche River Basins.

## 5. Public Participation

When EPA establishes a TMDL, 40 C.F.R. § 130.7(d)(2) requires EPA to publicly notice and seek comment concerning the TMDL. Pursuant to an October 1, 1999, Court Order, EPA prepared this TMDL. After submission of this TMDL to the Court, EPA commenced preparation of a notice seeking comments, information and data from the general and affected public. Comments and additional information were submitted during the public comment period and this Court Ordered TMDL was revised accordingly. EPA has transmitted this revised TMDL to the Court, and to the Louisiana Department of Environmental Quality (LDEQ) for incorporation into LDEQ's current water quality management plan.

## REFERENCES

Hem, John D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. Third Edition. United States Geological Survey Water-Supply Paper 2254. U.S. Government Printing Office

Louisiana Department of Environmental Quality. 1993. *State of Louisiana Water Quality ManagementPlan, Volume 6, Part A: Nonpoint Source Pollution Assessment Report*. Louisiana Department of Environmental Quality, Office of Water Resources, Baton Rouge.

## APPENDIX A. SULFATE AND TDS DATA

http://www.deq.state.la.us/surveillance/wqdata/0671wqng.txt

and

http://www.deq.state.la.us/surveillance/wqdata/0671wqnf.txt

| Date | Sulfate mg/l | Field Conductivity umhos | Estimated TDS* mg/L |
|---|---|---|---|
| 12/2/98 | 8.3 | 188 | 192 |
| 11/18/98 | 7.1 | 127 | 130 |
| 11/5/98 | 39.5 | 387 | 395 |
| 10/21/98 | 53.7 | 461 | 470 |
| 10/7/98 | 35.8 | 358 | 365 |
| 9/16/98 | 5.8 | 120 | 122 |
| 9/2/98 | 39.6 | 394 | 402 |
| 8/19/98 | 30.9 | 387 | 395 |
| 8/5/98 | 35.2 | 331 | 338 |
| 7/22/98 | 40.9 | 417 | 425 |
| 7/8/98 | 41.0 | 395 | 403 |
| 6/16/98 | 46.6 | 435 | 444 |

*Estimated TDS by multiplying field conductivity by 1.02 mg/l/*u*mho. This multiplier was calculated using data from a similar site (Station 0101). ANOVA showed no statistically significant differences between the two data sets.

Note: The 30 mg/L and 220 mg/L criteria for sulfate and TDS, respectively, were exceeded in 9 out of 12 sampling events.

Average estimated TDS concentration = 340 mg/L TDS
Average Sulfate concentration = 32.0 mg/L

(Reference: http://222.deq.state.la.us/surveillance/wqdata/0671wqng.txt …0101wqng.txt)

## APPENDIX B. FLOW CALCULATION METHODOLOGY

| Subseg | area | rate | flow(cfs) | Subseg | area | rate | flow(cfs) | Subseg | area | rate | flow(cfs) | Flow at Subsegment end | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | cfs | MGD | Subsegment |
| 060101 | 84.54 | 1.604 | 135.602 | | | | | | | | | 136 | 88 | 060101 |
| 060102 | 155.48 | 1.604 | 249.39 | | | | | | | | | 385 | 249 | 060102 |
| | | | | 060203 | 36.82 | 1.604 | 59.0593 | | | | | 59 | 38 | 060203 |
| 060201 | 81.76 | 1.604 | 131.143 | | | | | | | | | 575 | 372 | 060201 |
| 060202 | 70.01 | 1.604 | 112.296 | | | | | | | | | 687 | 444 | 060202 |
| 060208 | 269.23 | 1.604 | 431.845 | | | | | | | | | 1119 | 723 | 060208 |
| | | | | 060212 | 207.30 | 1.071 | 222.018 | | | | | 222 | 143 | 060212 |
| | | | | 060207 | 222.50 | 1.071 | 238.298 | | | | | 460 | 298 | 060207 |
| | | | | 060204 | 188.10 | 1.071 | 201.455 | | | | | 662 | 428 | 060204 |
| 060210 | 96.25 | 1.606 | 154.578 | | | | | | | | | 1936 | 1251 | 060210 |
| Trans out | | | -1131 | | | | | | | | | | | Trans out |
| 060205 | 50.34 | 1.606 | 80.846 | | | | | | | | | 886 | 572 | 060205 |
| Trans out | | | -413.3 | | | | | | | | | | | Trans out |
| 060301 | 12.62 | 1.606 | 20.2677 | | | | | | | | | 492 | 318 | 060301 |
| 060401 | 27.76 | 1.606 | 44.5826 | | | | | | | | | 537 | 347 | 060401 |
| | | | | **060211** | **93.66** | **1.606** | **150.418** | | | | | **150** | **97** | **060211** |
| | | | | Trans in | | | 206.63 | | | | | | | Trans in |
| | | | | 060703 | 151.50 | 1.606 | 243.309 | | | | | 600 | 388 | 060703 |
| | | | | | | | | 060701 | 26.59 | 1.071 | 28.4779 | 28 | 18 | 060701 |
| | | | | 060702 | 98.10 | 1.606 | 157.549 | | | | | 786 | 508 | 060702 |
| 060601 | 2.83 | 1.606 | 4.54498 | | | | | | | | | 1328 | 858 | 060601 |
| | | | | 060501 | 62.27 | 1.606 | 100.006 | | | | | 100 | 65 | 060501 |
| | | | | | | | | 060907 | 39.25 | 1.606 | 63.0355 | 63 | 41 | 060907 |
| 060906 | 148.17 | 1.769 | 262.113 | | | | | | | | | 1753 | 1133 | 060906 |

The flow at the outfall of each subsegment was calculated based on the area of the subsegment and a rate that predicts the flow per square mile of area. Six stations were used to establish the rates and calibrate the flows at the observed stations. ***The stations were used as appropriate to the drainage area under consideration***. This method uses the gage flow to be a composite of the base flow of the steam, the rainfall runoff on the drainage area above that point, the distributaries, the withdrawals from the stream, the point discharges, and return flow of the withdrawals from the stream. Six stations were used to prepare the subsegment flows for basins 5 and 6. The stations were 08012000 on Bayou Nezpique; 08010000 on Bayou Des Cannes; 07382500 on Bayou Courtableau; 07383500 on Bayou Des Glaises; 07385500 on Bayou Teche, Arnaudville; 07385700 on Bayou Teche, Keystone. The subsegment relationships are graphically represented in the table presented above. An Ishikawa type diagram was used to represent the tributary system of the basin in a spreadsheet format. Each row of the spreadsheet represents one subsegment, or a subsegment transfer flow. The subsegment number for the row will be listed in one of three columns. The far left column has the subsegments that represent the main stem of the stream, flowing from the top of the page down. Tributary subsegments are listed in the second or third column with the label "Subseg". The point that the tributary flows into the main

stem is represented by a horizontal line under the segment number extending to the left and intersecting with the column one vertical line (which represents the main stem). Multiple subsegments on a tributary will be depicted with a vertical in the "Subseg" column, with horizontal lines tying into it. The lowest tributary subsegment that flows into the main stem will have a horizontal line under the segment number extending to the left and intersecting with the column one vertical line. A tributary to a tributary will be shown in the third column labeled "Subseg". For readability, the subsegment number has been repeated in the last column on the right. To obtain the average flow at the outflow of a segment, find the subsegment number in the far right column. The column to the left will be the flow in MGD, the column to the left of that will be the flow in CFS. The flow for subsegment 060211 (listed in bold in the table above) was calculated to be 150 cfs.

## APPENDIX C. ANALYSES OF VARIANCE (ANOVA)

| Sulfate 1998 | Sulfate 1990 | |
|---|---|---|
| Sta0671 | Sta101 | |
| 8.3 | 21.6 | |
| 7.1 | 47.2 | |
| 39.5 | 48.0 | |
| 53.7 | 46.8 | |
| 35.8 | 45.4 | |
| 5.8 | 20.5 | |
| 39.6 | 22.3 | |
| 30.9 | 14.0 | |
| 35.2 | 13.3 | |
| 40.9 | 7.1 | |
| 41.0 | 4.4 | |
| 46.6 | 7.7 | |
| 5.8 | 4.4 | min |
| 53.7 | 48 | max |
| 32.0 | 24.9 | avg |
| 16.1 | 17.2 | stdev |
| 12 | 12 | count |

Anova: Single Factor (Sulfate)

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Sta0671 | 12 | 384 | 32.03333333 | 259.2987879 |
| Sta101 | 12 | 298 | 24.85833333 | 295.8226515 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 308.88375 | 1 | 308.88375 | 1.112851092 | 0.30291111 | 4.300943601 |
| Within Groups | 6106.335833 | 22 | 277.5607197 | | | |
| Total | 6415.219583 | 23 | | | | |

APPENDIX C. Continued

| Cond 1998 | Cond 1990 | |
|---|---|---|
| Sta0671 | Sta101 | |
| 188 | 210 | |
| 127 | 104 | |
| 387 | 352 | |
| 461 | 357 | |
| 358 | 432 | |
| 120 | 137 | |
| 394 | 459 | |
| 387 | 404 | |
| 331 | 382 | |
| 417 | 361 | |
| 395 | 359 | |
| 435 | 375 | |
| | | |
| 120 | 104 | min |
| 461 | 459 | max |
| 333.3 | 327.7 | avg |
| 119.4 | 114.0 | stdev |
| 12 | 12 | count |

Anova: Single Factor (Conductivity)

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Sta0671 | 12 | 4000 | 333.3333333 | 14245.33333 |
| Sta101 | 12 | 3932 | 327.6666667 | 12993.15152 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 192.6666667 | 1 | 192.6666667 | 0.014146651 | 0.90640252 | 4.300943601 |
| Within Groups | 299623.3333 | 22 | 13619.24242 | | | |
| | | | | | | |
| Total | 299816 | 23 | | | | |